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1 482 464

(54) ELECTRIC RESISTANCE HEATERS

(71) We, BOC INTERNATIONAL LIMITED (formerly known as The British Oxygen Company Limited), an English company trading as Edwards High Vacuum International of Manor Royal, Crawley, Sussex, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electric resistance heaters of the type which utilises a permeable body of electroconductive material through which is forced the fluid to be heated. The permeable body has Joule heat generated in it, and exchanges heat with the colder fluid flowing through the permeable body.

The design parameters of this type of heater are discussed in detail in UK Specification 1,182,421 and consideration of these parameters results in the preferred geometry are shown to be due to the relatively low resistivity of carbon, making it desirable to use thin wall sections, with the electrical connections arranged so that the current flow is parallel with the axis of the cylinder. These connections are provided with protruberances, as by being knurled or grooved, to provide intimate electrical contact with the fibrous carbon element. The fluid flow is arranged to be at right angles to the cylinder axis through the thin wall, either from the outside in or from the inside out. The use of a thin wall results in a steep temperature gradient being established through the thickness of the wall, which can lead to the incoming fluid being heated before entry to the element. The above specification describes the use of a thermal barrier to minimise this preheating effect and also to provide a means for ensuring uniform fluid flow through the element, which is essential if the formation of hot spots in the element is to be avoided or reduced.

It can be argued that the problem associated with a steep temperature gradient can be limited by arranging the fluid flow through the element wall to be in the direction of the axis of the element, of which the length is usually much greater than the radial wall thickness. Typically the element length may be 100 mm compared with a 5 mm wall thickness. This would result in a much-reduced temperature gradient when the same rates of flow and of power generation are used. Because of the reduced cross-sectional area for fluid flow the fluid velocity will be increased and this, in combination with the shallower temperature gradient, will reduce the possibility of pre-heating of the incoming fluid, and therefore the necessity for using a barrier of low thermal flow conductivity.

In a possible arrangement of this known heater, the fluid flow could be through the wall of the element parallel to the element axis. The element wall would have to be enclosed internally and externally in a suitable electrically insulating impermeable material to constrain the fluid, with fluid entry and exist vents being situated close to the electrical connections. This arrangement would result in the fluid having to turn through a right-angle at the inlet and exit vents. These turns would result in non-uniform flow across the entry and exit areas, with the likelihood of there being regions of stagnant flow in which local over-heating would occur. This overheating could result in damage to the fluid and/or to the electrical connections.

The present invention aims at providing a permeable element heater exploiting the advantage of fluid flow in the element in the direction parallel to the element axis while facilitating uniform fluid flow throughout the element.

The present invention accordingly provides an electric resistance heater which is as claimed in the appended claims.

The present invention will now be described by way of example with reference to the accompanying drawing, in which:—

Figure 1 is a cross-sectional view of a permeable electric resistance heater of the present invention;

Figure 2 is a cross-sectional view of a second form of heater of the present invention adapted to produce a mixture of hot and cold fluids;

Figure 3 is a cross-sectional view of a heater similar to that shown in Figure 2, but with the positions of the electrical terminals altered, and

Figure 4 is a diagrammatic view of a modified heater of the present invention.

The heater shown in Figure 1 has a cylindrical body 2 in the form of a glass tube. Positioned on the ends of tube 2 is a pair of hollow cylindrical terminals 4 which have a source 6 of heating current connected across them. Positioned in the interior of tube 2 in electrical contact with the terminals 4, are two plugs (or electrodes) 8 of circular cross-section. Each of the plugs 8 has a high electrical conductivity so that a negligible amount of Joule heat is released in it when an electric heating current flows through the plug from the contiguous terminal 4. The plug of such a known permeability as to present a predetermined impedance to the flow through it of the fluid which is to be heated. One method of providing a plug 8 having the necessary electrical conductivity and fluid impedance is to form the plug of sintered metal. The sintering process is controlled so that the resultant plug has the desired characteristics.

Another method of providing a plug 8 having the necessary electrical conductivity and fluid impedance is to form the plug of permeable metal of the type known as Retimet (registered Trademark). This is available in most metals and with a wide range of pore sizes.

Packed relatively tightly in the interior of the chamber 10, bounded by the inner surface of tube 2 and the plugs 8, is a material which is also permeable to the fluid and which has a significant electrical resistance. One suitable form of material 12 consists of a body carbon fibres, or a matrix of a thermally-stable fibrous material having the fibres coated with carbon. The interstitial spaces between the fibres present a chosen impedance to the flow of fluid between the ends of tube 2, so that a known pressure drop between the inlet and outlet ends of the tube results in fluid flowing through the heater at a known rate.

The electrical resistance of the material 12 is also chosen so that the Joule heat is released in material 12 at a known rate, thus raising the temperature of the incoming fluid by a chosen amount. It will be appreciated that the actual temperature rise can be adjusted by altering the voltage of the power source 6.

In the remaining figures of the drawing, those parts which are as the same as, or equivalent to, components shown in the Figure 1, have been given the same reference numerals.

The form of heater shown in Figure 2 has a central tube 14 of electrical insulation material. The fluid to be heated is introduced into a plenum chamber 16, while a supply of cold fluid passes through the interior of tube 2. The resultant heated fluid and the cold fluid are mixed in an outlet chamber 18. Normally the rate of flow of liquid through chamber 10 is kept fixed, e.g. by ensuring that it is supplied with fluid at a constant pressure, or by a constant displacement pump, so that the temperature of the heated fluid entering the chamber 18 is always the same. This means that the temperature of the mixed fluid leaving chamber 18 can be controlled by altering the rate at which cold fluid is supplied to the inner tube 14.

The heater shown in Figure 3 is basically the same as that shown in Figure 2, with the exception that it is provided with an extra internal tube 20 of metal or other conductive material. Tube 20 projects from the inlet end of the tube 2 (which is made of electrical insulation material) so as to enable one side of the power source 6 to be connected to it. The other end of tube 20 is in contact with terminal 22: this causes the tube 20 to act as a return path for the heating current, so that the source 6 is able to be connected to the heater at the same end, which can be advantageous in some constructions of heater.

The electrical current enters tube 20 through a hollow cylindrical terminal 22 positioned at the outlet end of tube 14. Because of the high electrical conductivity of the plug material this has virtually no effect on the path followed by the heating current, which flows virtually substantially longitudinally between the plugs 8.

In that form of heater shown in Figure 4, the actual heating elements 24 are of the type shown in Figure 1. Several such elements (of which only four are illustrated) are positioned in a body 26 provided with an inlet chamber 28 and an outlet chamber 30. It will be seen that each heater 24 acts as a fluid flow path between chambers 28 and 30, so that the effective cross-sectional area of flow is the sum of the individual cross-sections of the heaters 24. However, although the fluid flows through the heaters 24 in parallel with each, the electrical heating current is arranged to flow in series through heaters 24.

In this way a fluid flow several times greater than in the case of simple path heaters can be heated, without the need for excessive heating currents.

It will be apreciated that the combined heater shown in Figure 4 could be modified, by incorporating heaters of the kind shown

in Figure 2 or Figure 3, so that the heater could be used in a mixer unit to produce water or other fluid of which the outlet temperature can be controlled.

WHAT WE CLAIM IS:—

1. An electrical heater for fluids, including at least one tubular body of non-electroconductive material; an axially-extending electrode at each end of the body and formed of material which is uniformly permeable by the fluid to be heated, which electrodes cooperate with the inner surfaces of the intermediate portion of the tubular body to define a closed chamber, and a mass of fluid-permeable and electroresistive material filling the chamber and in electrical contact with the electrodes.

2. A heater as claimed in claim 1, wherein a further tube of electrical insulation material extends through the said tubular body and through apertures provided in the electrodes so as to define the said closed chamber, with the tubular body and the electrodes, wherein there is provided at one end of the tubular body a fluid inlet communicating with the space between the tubular body and the further tube, through which inlet a flow of fluid is in use passed into the closed chamber, and at the other end of the tubular body a fluid outlet chamber which is arranged to receive in use both fluid which is heated in the closed chamber, and fluid which is passed in use through the interior of the further tube.

4. A heater as claimed in any of the preceding claims, wherein each electrode is in contact with a terminal in the form of a sleeve of electrically-conductive material located at a respective end of the tubular body to provide an extension thereof.

5. A heater as claimed in claims 3 and 4, wherein one of the terminals is located at one end of the tubular body; wherein the other terminal is located at the other end of the further tube, and wherein a lining of electrically-conductive material is provided within the further tube and in electrical contact with the said other terminal whereby a power source can be connected in use at the same end of the heater between the said one terminal and the nearer end of the lining to provide the aforesaid potential difference between the terminals.

6. A heater as claimed in claim 5, wherein the lining is provided by a tube of electrically-conductive material fitting closely within the further tube and projecting therefrom at said one end of the heater.

7. A heater as claimed in any of claims 4 to 6, wherein the tubular body and the further tube are coaxial.

8. A heater as claimed in any of the preceding claims, wherein the tubular body is made of glass.

9. A heater as claimed in any of the preceding claims, wherein the electrodes are made of sintered metal.

10. A heater as claimed in any of claims 1 to 8, wherein the electrodes are made of metal presenting uniform permeability to the fluid to be heated.

11. A heater as claimed in any of the preceding claims, wherein the said fluid-permeable mass in the closed chamber is provided by a body of carbon fibres.

12. A heater as claimed in any of claims 1 to 9, wherein said fluid-permeable mass is provided by a matrix of fibrous material having the fibres coated with carbon.

13. An electrical heater for fluids, substantially as hereinbefore described with reference to, and as shown in, any one of Figures 1 to 3 of the accompanying drawings.

14. An assembly of several heaters as claimed in any one of claims 1 to 13 located side by side, in a housing, the housing having a fluid inlet chamber arranged to provide a common inlet through which fluid can be passed in use into the said closed chamber of each heater, and an outlet chamber for receiving in use the heated fluid issuing from the closed chambers of the heaters.

15. An assembly of several electrical heaters for fluid, substantially as hereinbefore described with reference to, and as shown in, Figure 4 of the accompanying drawings.

For the Applicants:
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Chartered Patent Agent.

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1482464 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

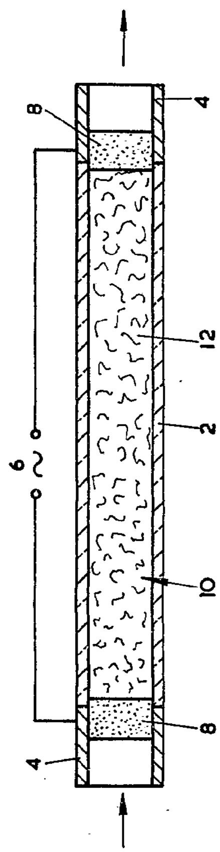

FIG.1

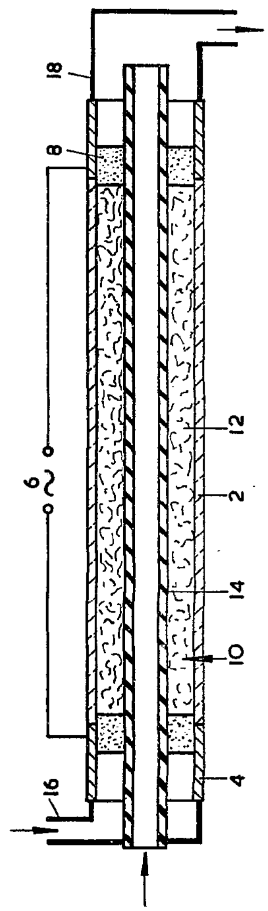

FIG.2

1482464 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

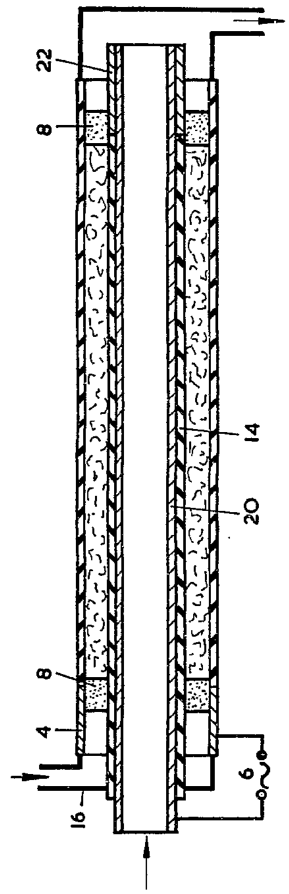

FIG.3

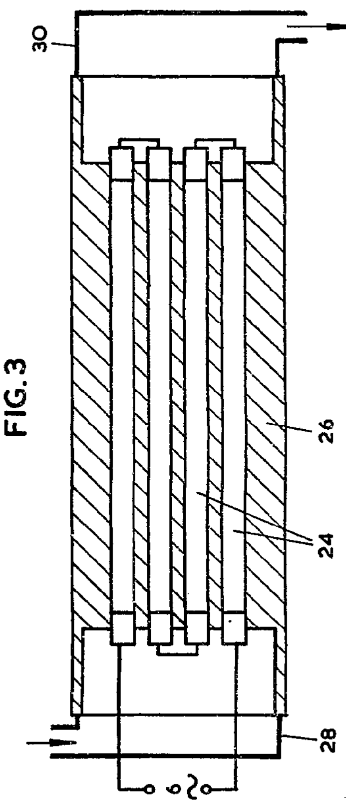

FIG.4